

[54] **AUTOMATIC CORRECTION OF  
CENTERING AND CONVERGENCE ERRORS  
IN CRT DISPLAYS**

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H01J 29/70

[52] **U.S. Cl.** ..... 358/10; 358/139;  
315/368

[58] **Field of Search** ..... 358/10, 139, 69;  
315/13.1, 13.11, 368, 370

[56] **References Cited**

**U.S. PATENT DOCUMENTS**

3,479,448	11/1969	Kollsman	358/10 X
3,962,722	6/1976	Ciciora	358/10
4,001,877	1/1977	Simpson	358/10
4,035,834	7/1977	Drury	358/10
4,364,079	12/1982	Pons	358/10
4,485,394	11/1984	Ghaem-Maghami et al.	358/10

4,551,748 11/1985 Matile ..... 358/10

**FOREIGN PATENT DOCUMENTS**

0099882 7/1980 Japan ..... 358/10

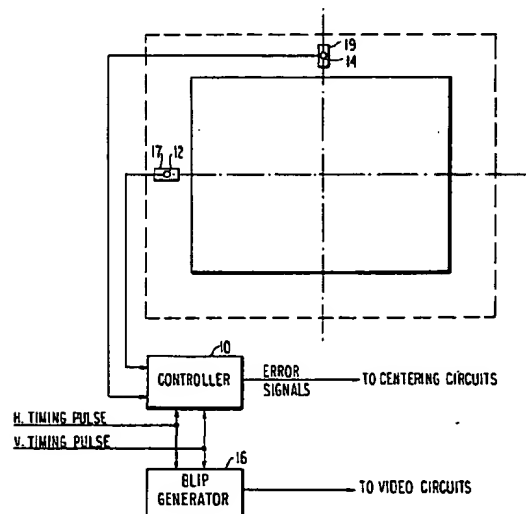
*Primary Examiner*—Michael A. Masinick

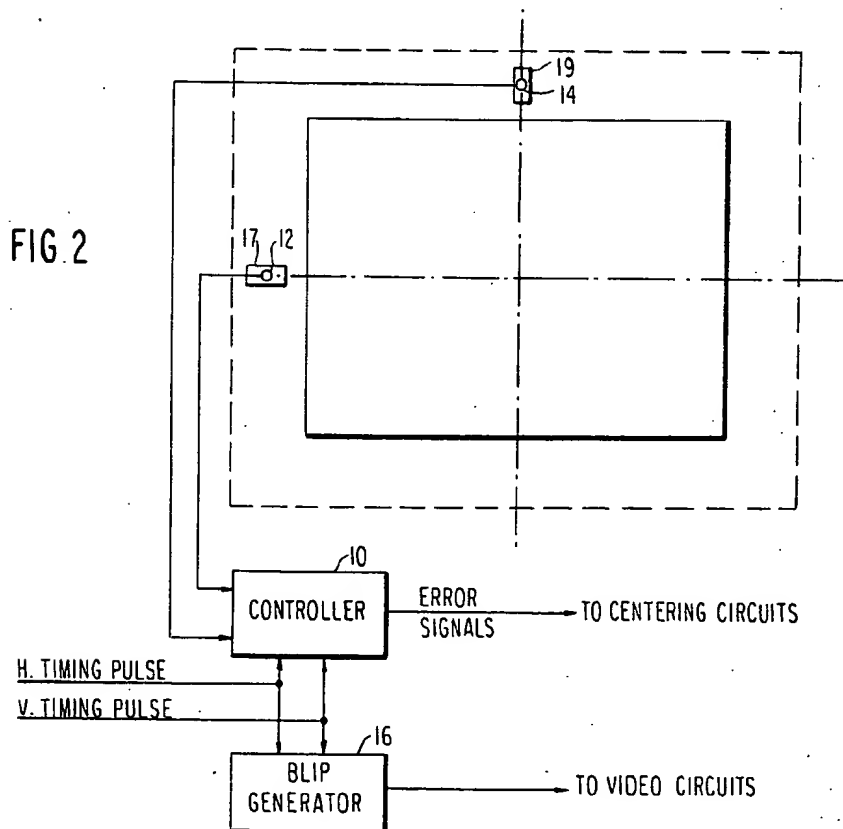
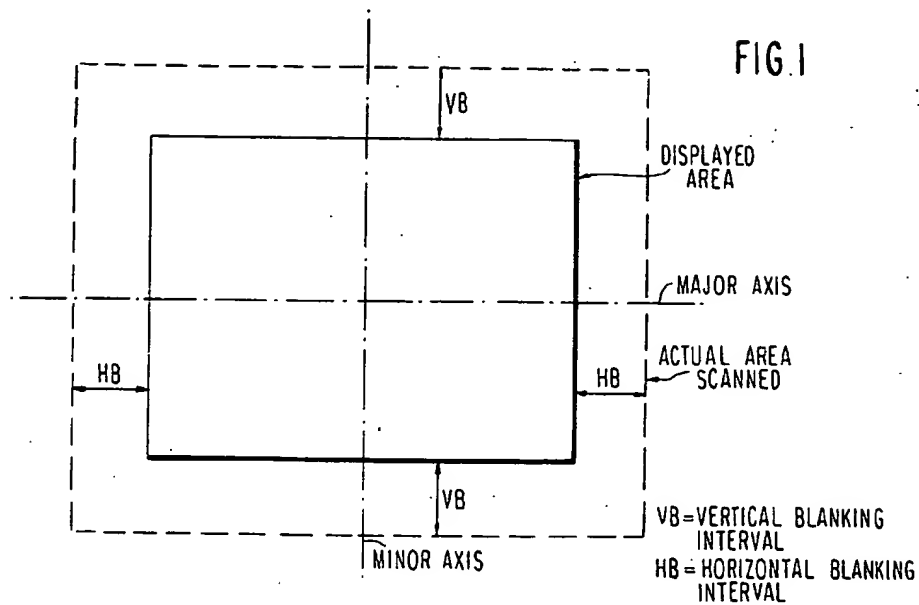
*Assistant Examiner*—Michael P. Dunnam

[57] **ABSTRACT**

An improved system for the automatic correction of centering and convergence errors in a cathode ray tube display is disclosed. The system includes a first masked light sensor (12) positioned on the major axis of the display and a second masked light sensor (14) positioned on the minor axis of the display. A light blip generator (16) is responsive to the horizontal and vertical timing pulses for unblanking the video circuits during the horizontal and vertical blanking intervals in order to generate light pulses in the vicinities of said first and second light sensors. A microprocessor based feedback controller (10) is responsive to the outputs of the light sensors and programmed to iteratively generate correction signals whenever no output is received from one or both of the light sensors.

**4 Claims, 8 Drawing Figures**





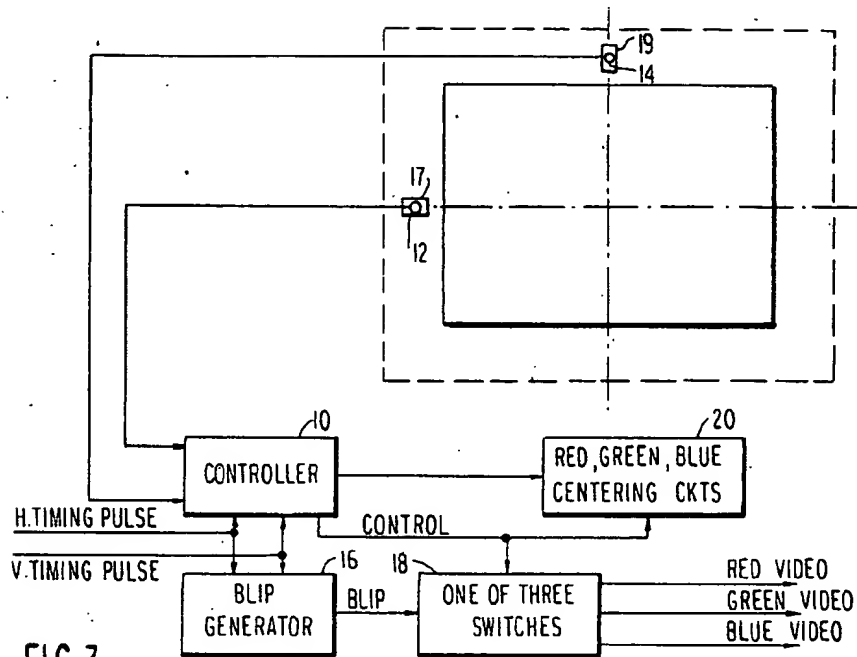


FIG. 3

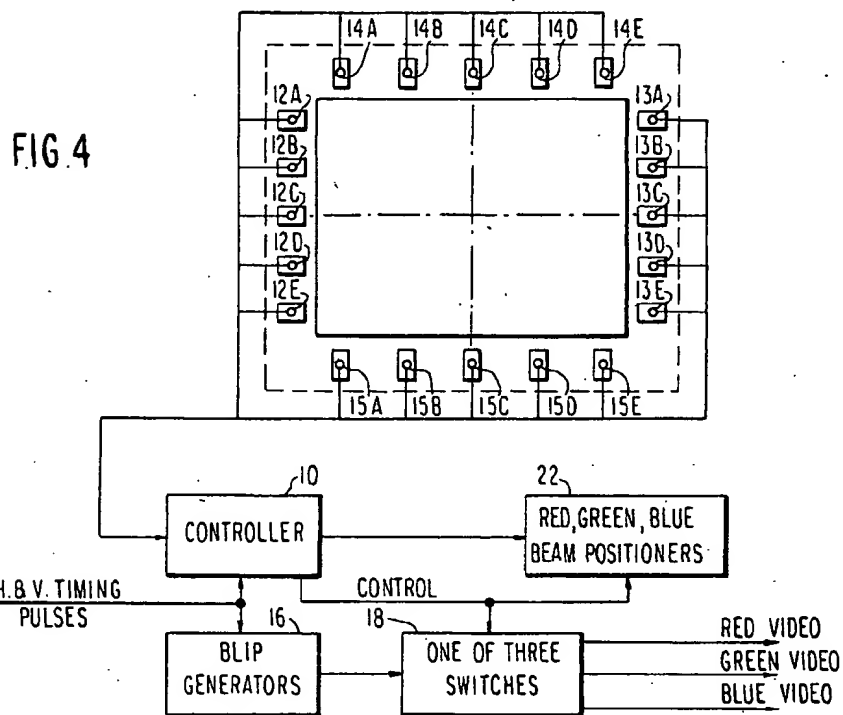
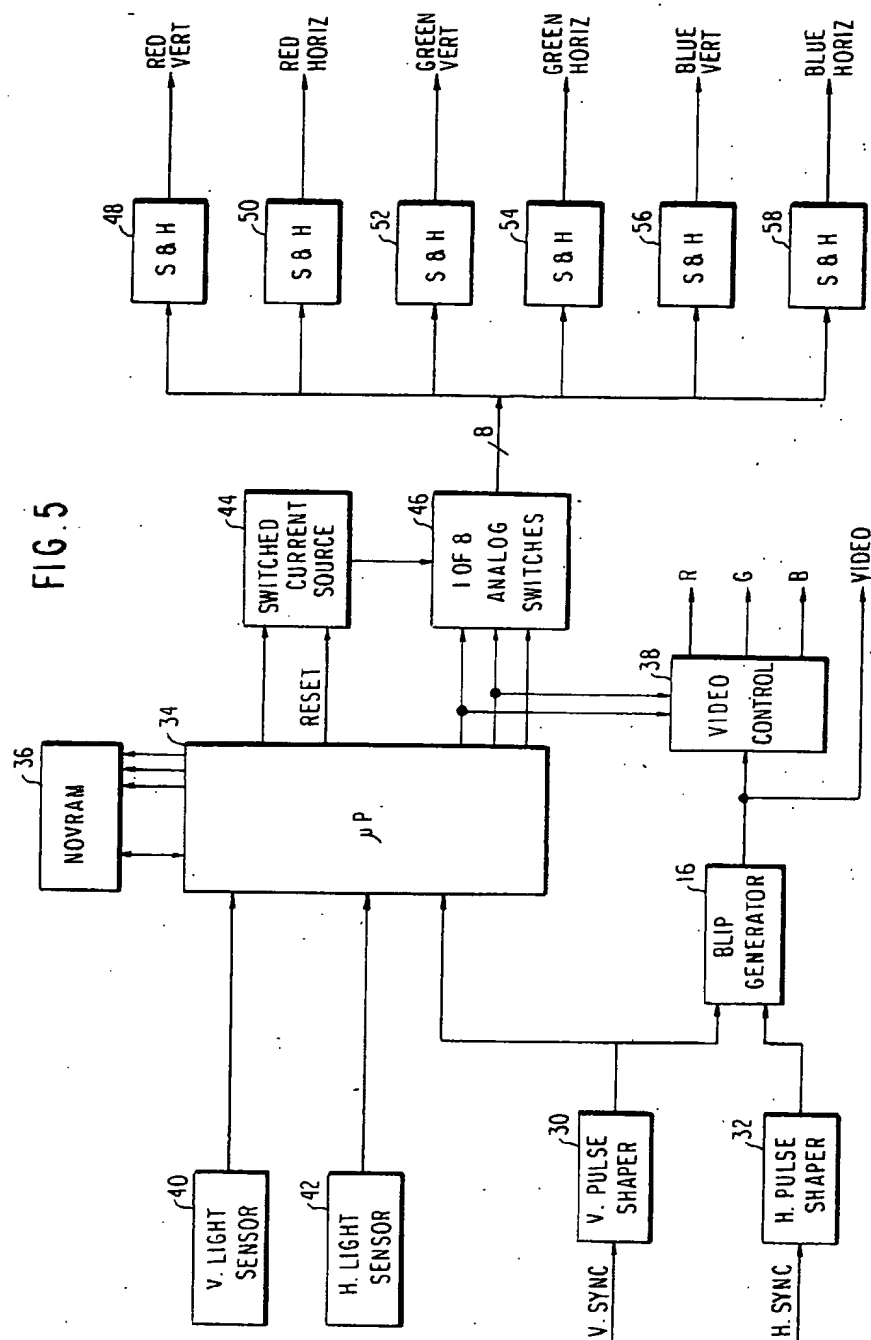


FIG. 4



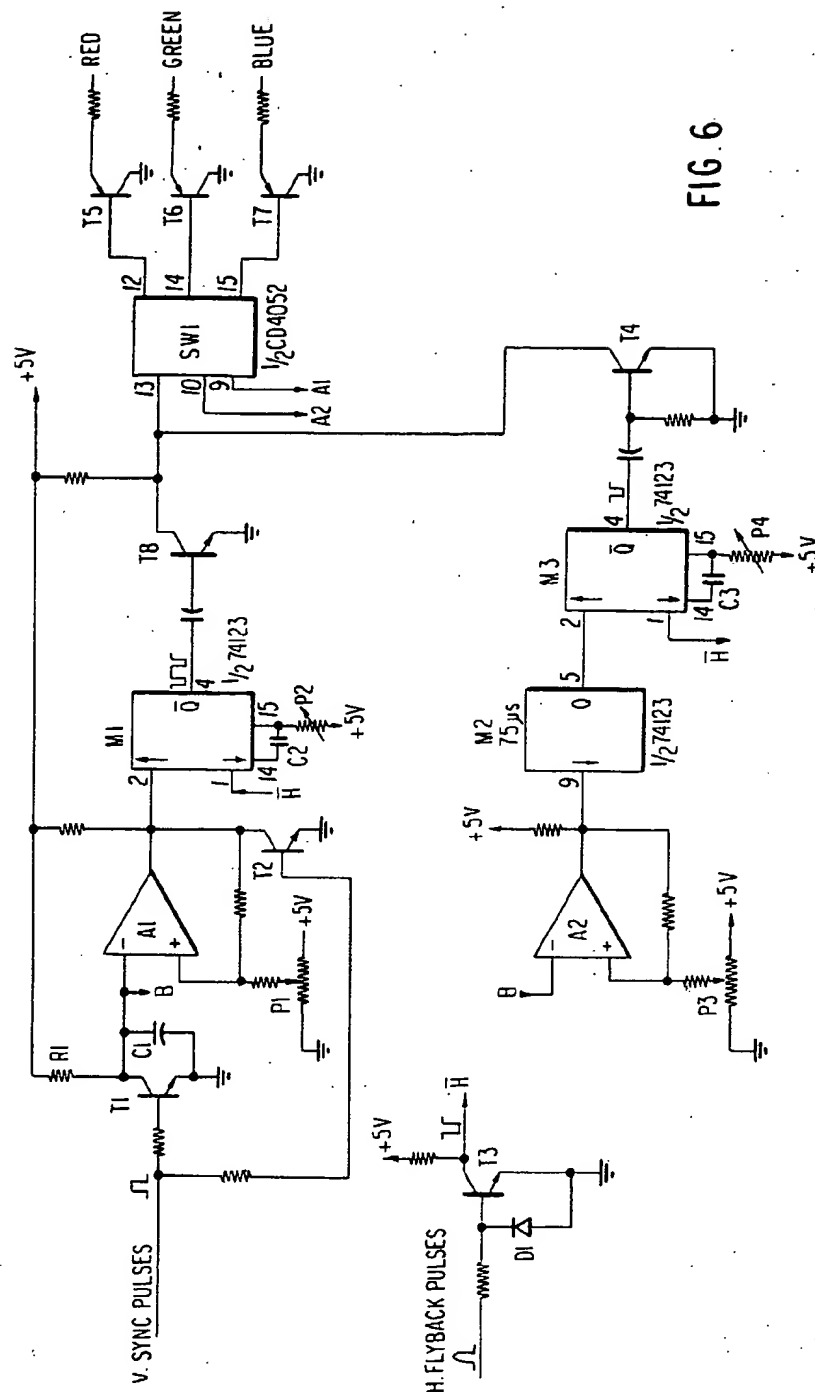
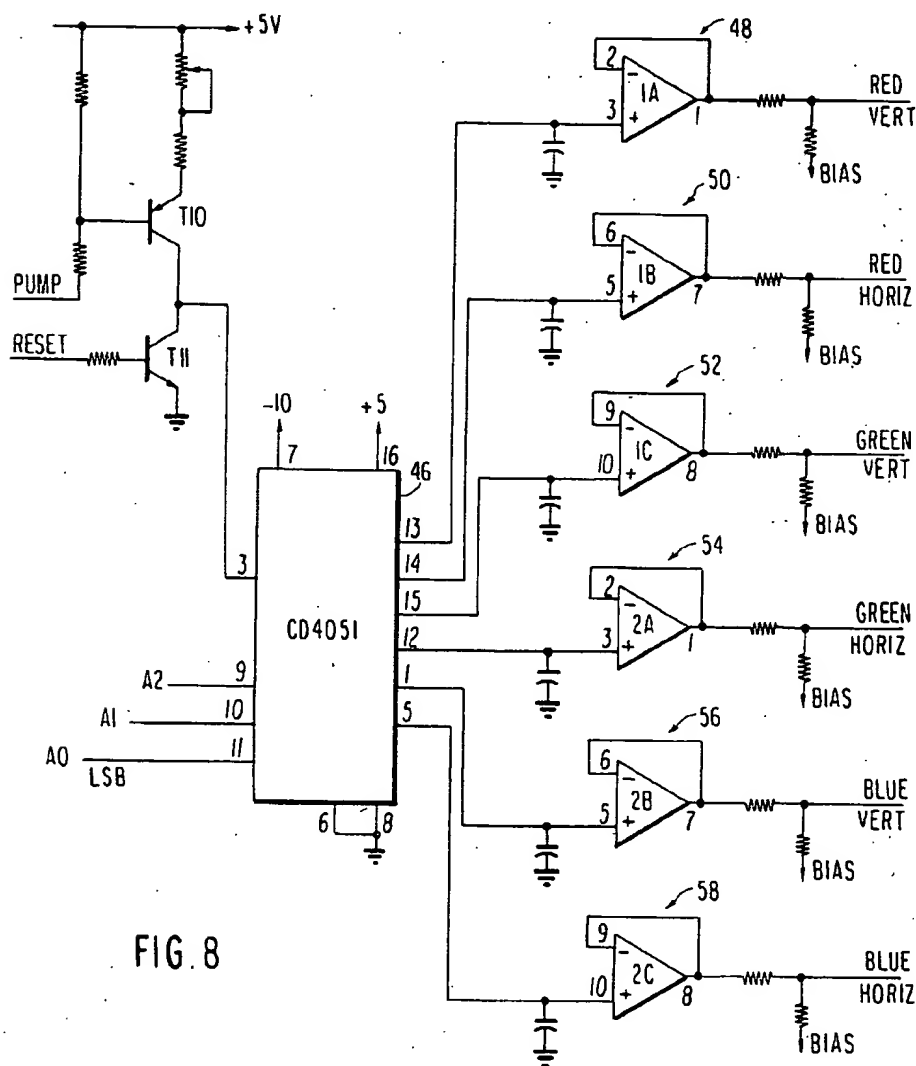
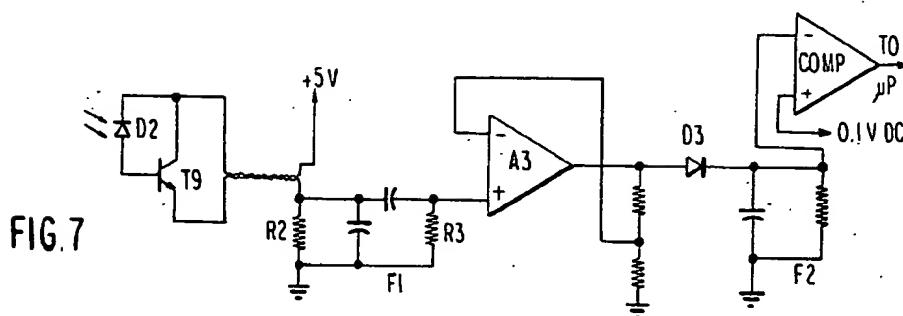


FIG. 6



# **AUTOMATIC CORRECTION OF CENTERING AND CONVERGENCE ERRORS IN CRT DISPLAYS**

## **RELATED APPLICATION**

The present application is related to application Ser. No. 423,906 filed Sept. 27, 1983, (now U.S. Pat. No. 4,485,394) by Sanjar Ghaem-Maghani and Howard Eugene Holshouser entitled "Automatic Convergence and Gray Scale Correction for Television Receivers and Projection Television Systems" and assigned to the assignee of this application.

## **BACKGROUND OF THE INVENTION**

The invention generally relates to the correction of centering and convergence errors in cathode ray tube (CRT) displays, and more particularly to a method and apparatus for the automatic correction of such errors during normal operation of the display.

CRT displays, whether they be monitors, television receivers or projection systems, periodically require adjustments to be made to maintain proper centering of the displayed image. Color CRT displays of the type having three cathode ray beams and a screen with a mosaic of phosphor dots or stripes of recurring groups of three colors must be adjusted to maintain the convergence of the three beams over the visible surface of the screen. An analogous adjustment must be made for projection displays employing three projection CRTs. These adjustments are initially made at the factory, but with age, temperature and other environmental conditions, it is necessary to readjust centering and convergence in order to maintain the quality of the displayed image. Ordinarily this is accomplished by a skilled technician with test instruments. The test instruments used to measure convergence often resort to the use of an appliance that is placed over the CRT screen to facilitate detection of the landing point of the cathode ray beam. Such an appliance obscures the screen, and therefore these instruments are not intended to be used simultaneously with the viewing of the display. Examples of such instruments are U.S. Pat. No. 4,001,877 issued to Theodore Frederick Simpson and U.S. Pat. No. 4,035,834 issued to Anthony M. Drury.

The Simpson patent describes a test instrument that employs a photosensitive array comprising a plurality of individual photo cells, this array being placed over the CRT screen. Further, a special post-deflection coil is required to introduce magnetic fields in the region just forward of the deflection yoke to displace the scanned beams in a controlled pattern from their normal landing points on the screen. The displaced beam causes the emission of an error color, the intensity of which is measured by those photo cells which are sensitive to the error color emitted. The intensity of a reference color emitted by the phosphor deposits stimulated by the undisplaced beam is then measured, and the ratio of the error color to the reference is calculated for each measurement location on the screen. The largest ratio is displayed as an indication of the color purity tolerance of the CRT. The Simpson test instrument is used primarily as a quality control device in the manufacture of color CRTs.

The patent to Drury describes a beam landing indicator for a color CRT which also employs a holder for positioning a plurality of photo cells over the screen of the CRT. While the Drury instrument does not require a special deflection coil, it does employ a special deflec-

tion generator in order to produce a clockwise rotation of the beam landing shift of the beam. This rotation is stepped in increments which occur once each vertical field of the television raster. Light variations sensed by the photo cells are combined with a reference signal to control the dot location on an oscilloscope display of the vector beam landing error. The technician can then make purity adjustments and yoke adjustments of the CRT by observing the oscilloscope display.

Automating the adjustment of color television receivers is also known. An example is described in U.S. Pat. No. 3,962,722 issued to Walter S. Ciciora. More specifically, the Ciciora patent describes a color television setup apparatus for use in a factory. Once again, a holder positions a plurality of photo cells over the CRT screen in such a manner as to obscure the view of the screen. Patterns indicative of the characteristics of contrast, brightness, color and tint are displayed on the CRT. The photo cells develop corresponding electrical signals which are supplied to circuitry that energizes a plurality of bi-directional motors that are engageable with the receiver contrast, tint, brightness and color level adjustment elements.

While the systems described by Simpson, Drury and Ciciora are useful in a factory or shop environment, what is needed is an automatic means for adjustment of convergence which is part of the CRT display. In this way, the display would be continuously maintained in proper adjustment for optimum viewing. Such a system has been provided in the above-referenced application Ser. No. 423,906 (now U.S. Pat. No. 4,485,394) filed by Ghaem-Maghani and Holshouser. According to that invention, a system is provided for the automatic correction of convergence and gray scale which employs light sensors, either singly or in an array, on or adjacent to the beam landing surface of a CRT or on or adjacent to the screen of a projection receiver. The sensors can be placed proximate the overscanned area of the raster such that they are outside the normal viewing area, or in the viewing area if the sensors are made sufficiently small. In the vicinity of a sensor, two of the three cathode ray tubes or electron guns are blanked. As the light beam, in the case of a projection system, crosses the sensor, an output is produced. This output is processed to obtain accurate timing characteristics. Since the position of the sensor is known in terms of counts in both the vertical and horizontal directions, error signals can be developed by comparing the timing of the sensor output with the proper count. These error signals are used to develop vertical and horizontal correction signals to correct the convergence of the one cathode ray tube or gun. The process is then repeated for the remaining two cathode ray tubes or guns. The output of the sensor is also amplified by gated amplifiers for each of the cathode ray tubes or guns in sequential order, and the outputs of these amplifiers are compared to a preset value to develop error signals. These error signals are used to set gun drives to correct the gray scale.

The system described in application Ser. No. 423,906 (now U.S. Pat. No. 4,485,394) filed by Ghaem-Maghani and Holshouser generally operates well under most conditions; however, that system is affected by a change in picture size due to a change from a dark scene to a light scene, a change in line voltage, or a change in the blanking pulse transmitted by the television station, for example. The system is sensitive to both the amplitude and speed (slope) of the incoming light pulse. So while

the system according to Ghaem-Maghami and Holshauser operates satisfactorily, it is nevertheless desirable to improve on the performance of that system.

#### SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a system for the automatic correction of centering errors in cathode ray tube displays which is substantially insensitive to the amplitude and slope of the outputs from the light sensors.

It is another object of the invention to provide an improved system for the automatic correction of convergence errors in color cathode ray tube displays which accomplishes the convergence correction within a high degree of accuracy.

According to the present invention, two or more light pulses are generated in the vertical and horizontal blanking intervals. A corresponding number of optical sensors are positioned about the periphery of the viewable display to receive the light pulses. The outputs of these optical sensors are connected to a feedback-type controller. The controller corrects for centering errors by producing an error signal which alters the centering of the displayed image until the light pulses fall on the sensors. When the process is applied to all three colors sequentially, static convergence errors are corrected. If, in addition, information about the width and height of the actual scan is known, a device which can correct the instantaneous position of the beam is used, and a multiplicity of light pulses and sensors are used, dynamic convergence correction can also be accomplished. The present invention accomplishes a similar objective to that of the invention disclosed in Ser. No. 423,906 (now U.S. Pat. No. 4,485,394) filed by Ghaem-Maghami and Holshauser; however, this invention accomplishes that objective in a different way.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood from the following detailed description of the invention with reference to the drawings, in which:

FIG. 1 is a plan view of a CRT display showing the relationship between the displayed area and the actual area scanned;

FIG. 2 is a block diagram of a basic embodiment of the invention employing two optical sensors and a feedback-type controller;

FIG. 3 is a modification of the system shown in FIG. 2 for accomplishing static convergence corrections;

FIG. 4 is a further modification of the basic embodiment employing a plurality of optical sensors with the feedback-type controller for accomplishing dynamic convergence corrections;

FIG. 5 is a block diagram of a microprocessor based feedback-type controller for the embodiment shown in FIG. 3;

FIG. 6 is a schematic diagram of a blip generator which is used with the controller shown in FIG. 5;

FIG. 7 is a schematic diagram of an optical sensor circuit which is used with the controller shown in FIG. 5; and

FIG. 8 is a block and schematic diagram of the 1 to 8 analog switch, the switched current source circuit and the sample and hold circuits shown in FIG. 5;

#### DETAILED DESCRIPTION OF THE INVENTION

In a raster-scan CRT display, the electron beam actually scans past the edges of the displayed image, but it is normally blanked during this time. This is illustrated in FIG. 1 where the arrows VB indicate the vertical blanking intervals and the arrows HB indicate the horizontal blanking intervals. Notice also that the display area is bisected horizontally by a major axis and vertically by a minor axis. It is possible to generate one or more pulses which are timed to occur during the vertical and horizontal blanking intervals. These pulses are used in the present invention to unblank the display and cause the emission of a blip of light. Since this blip occurs during the blanking interval and the displayed image is normally set to fill the entire area which may be seen by the viewer, these light blips would not be seen.

If the centering of the displayed image is changed, the light blips will move along with the image. Thus, if optical sensors are positioned where the blips should fall physically, a feedback-type controller can be implemented which will correct for centering errors by producing error signals which alters the centering of the displayed image until the light blips fall on the optical sensors. A block diagram of this system is shown in FIG. 2 wherein the controller 10 receives as inputs the outputs of masked optical sensors 12 and 14 placed along the major and minor axes, respectively. Horizontal and vertical timing pulses are provided to both the controller 10 and the blip generator 16. In response to these timing pulses, the blip generator 16 provides an output which unblanks the video circuits causing light pulses to be generated at known timing intervals. The rectangles 17 and 19 surrounding the optical sensors 12 and 14, respectively, indicate blips of light produced when the displayed image is properly centered. Since the optical sensors are masked, they provide an output only if the blips of light are physically coincident with the sensors as indicated by the drawing. If the light blips 17 and 19 do not fall on the optical sensors, the controller 10 begins an iterative routine that produces an error signal which is supplied to the centering circuits.

If the process is applied to all three colors sequentially, using the same sensors 12 and 14, static convergence errors will also be corrected. This is accomplished by the system shown in FIG. 3 wherein the output of the blip generator 16 is supplied to a 1 of 3 analog switch 18 that generates in sequence unblanking pulses for the red, green and blue video signals. The output of the controller 10 is supplied, in corresponding sequence, to the red, green and blue centering circuits represented by block 20.

If, in addition, information about the width and height of the actual scan is known, a device which can correct the instantaneous position of the beam is used, and a multiplicity of blips and sensors are used, dynamic convergence correction can also be accomplished. Such a system is shown in FIG. 4 wherein a first plurality of vertical optical sensors 12A, 12B, 12C, 12D, and 12E are shown along the left edge of the display, a second plurality of vertical optical sensors 13A, 13B, 13C, 13D, and 13E are shown along the right edge of the display, a first plurality of horizontal sensors 14A, 14B, 14C, 14D, and 14E are shown along the top edge of the display, and a second plurality of horizontal sensors 15A, 15B, 15C, 15D, and 15E are shown along the

bottom edge of the display. The outputs of these optical sensors are supplied to the input of the controller 10 which generates an error output to the red, green and blue positioners represented by block 22.

Referring now to FIG. 5, there is shown a microprocessor based feedback controller for the system shown in FIG. 3. Vertical and horizontal sync pulses are supplied to vertical and horizontal pulse shapers 30 and 32, respectively. The outputs of these pulse shapers are provided to the blip generator 16 which is described in more detail hereinafter with reference to FIG. 6. The output of the vertical pulse generator 30 is also supplied to the microprocessor 34 to supply a timing reference. The output of the blip generator 16 is supplied to the video circuits as an unblanking signal and also to the video control 38. The video signal 38 may be the analog switch shown in FIG. 6. Note that a two-bit binary input is supplied to the video control from the microprocessor 34. This two-bit input is used to make the one-of-three switch selection. The vertical and horizontal light sensors 40 and 42 provide inputs to the microprocessor 34 when a light pulse is produced at their respective physical locations on the periphery of the display screen as shown in FIG. 3. If there are no light sensor inputs, the microprocessor 34 begins an iterative process that generates error signals to correct for red, green or blue centering errors as may be appropriate. More specifically, if the light sensors 40 and/or 42 do not receive a pulse of light when they are supposed to, the microprocessor begins a process of ramping up and down to achieve centering and static convergence. This is accomplished by means of the charge pump 44, the one-of-eight analog switch 46 and the sample and hold circuits 48 to 58. These are shown in more detail in FIG. 8.

Turning now to FIG. 6, there is shown the blip generator used in the controller system of FIG. 5. The vertical sync pulse is applied to the bases of NPN transistors T1 and T2. A capacitor C1 is connected across the emitter-collector circuit of transistor T1 so that when a positive going vertical sync pulse is applied to the base of transistor T1, the transistor conducts discharging capacitor C1. At the same time, transistor T2 conducts shorting the output of comparator A1 to ground. When the vertical sync pulse ends and transistors T1 and T2 are again nonconducting, capacitor C1 charges from the +5 V supply through load resistor R1. The ramping voltage across capacitor C1 is supplied to the negative input of comparator A1 as an analog timing signal. The positive or reference input to the comparator A1 is connected to the wiper of a potentiometer P1, the winding of which is connected between the +5 V supply and ground. The purpose of potentiometer P1 is to establish the vertical blip height. Thus, initially during a vertical sync pulse, the output of comparator A1 is forced low by the conduction of transistor T2, but immediately thereafter, the output of the comparator A1 is high. The output of the comparator A1 remains high until the ramping voltage across capacitor C1 exceeds the voltage set by potentiometer P1. In effect, a number of horizontal scans at the beginning of the field is selected by adjusting the potentiometer P1.

The output of comparator A1 is connected to pin 2 of a monostable multivibrator M1 which may be one half of a standard commercial 74123 integrated circuit (IC). A positive voltage on pin 2 enables the monostable M1. The horizontal flyback pulses are supplied to the base of an NPN transistor T3 connected in grounded emitter

fashion with a diode D1 connected between the base-emitter circuit. Thus, transistor T3 functions as a clipping inverter. The negative going pulses from the collector of transistor T3 are supplied to pin 1 of the monostable M1. Connected between pin 15 of the monostable M1 and the +5 V supply is a variable resistor P2, and connected between pins 14 and 15 is a capacitor C2. The monostable M1 is triggered by the negative going horizontal timing pulses and times out at a time determined by the RC time constant of P2 and C2. The monostable output goes low immediately and then returns high at the end of the time period determined by P2 and C2. Thus, the monostable M1 produces a negative going pulse having a width determined by the capacitance of capacitor C2. In this way, the monostable M1 provides a series of negative going pulses, one each horizontal scan, as long as it is enabled by a positive output from comparator A1. These pulses are produced at some point along the horizontal scan as determined by the RC time constant P2C2. In other words, adjustment of the potentiometer P2 is made to locate the blip on the minor axis (see FIG. 1) at the top of the display. This blip occurs outside the field of view as determined by the setting of potentiometer P1. When the output of monostable M1 returns to the high state, a pulse is coupled to the base of transistor T8 causing its collector to go low. The width of this pulse is determined by the value of the capacitor in the base of transistor T8 and thereby determines the width of the pulse on the minor axis.

The comparator A2 is similar to comparator A1 receiving as it does the ramping voltage across capacitor C1 at its negative input and a voltage from potentiometer P3 at its positive or reference input. At the beginning of a vertical scan, the output of comparator A2 is positive, but at some point as determined by the setting of potentiometer P3, the output of comparator A2 goes low. The negative going output of comparator A2 triggers monostable M2 which times out after a period of between one and two horizontal scans or about 75  $\mu$ sec. During this time, the output of monostable M2 is positive and enables monostable M3. This provides a window during which only one negative going horizontal timing pulse from transistor T3 can trigger the monostable M3. Like monostable M1, the monostable M3 is provided with a variable resistor P4 connected between pin 15 and the +5 V supply and a capacitor C3 connected between pins 14 and 15. The RC time constant of P4C3 determines the width of the output pulse. Thus, by adjusting potentiometer P3, the pulse at the left edge of the display can be positioned to fall on the major axis (see FIG. 1), and by adjusting potentiometer P4, the pulse width can be adjusted so as to be outside the field of view.

The negative going pulses from monostables M1 and M3 are capacitively coupled to the bases of NPN transistors T8 and T4, respectively. These transistors serve as drivers and their collectors are connected to pin 13 of an analog switch SW1. The switch SW1 may be one half of a standard commercial CD4052 IC which functions as a one-of-three switch controlled by a two-bit binary code supplied to pins 9 and 10 from microprocessor 34 (see FIG. 5). Switch SW1 connects pin 13 to pins 12, 14 or 15 as determined by the binary code. These pins are, in turn, connected to the bases of NPN transistors T5, T6 and T7 which supply unblanking pulses to the video circuits.

The blip that is generated on the vertical axis requires applying a narrow pulse to the cathode of the electron gun. The width of this pulse, and thus the bandwidth needed in the video circuits, is dependent upon the viewable diagonal measurement (DM), the allowable convergence error (CE), the aspect ratio (AR), and the active scan time (AST). The aspect ratio is defined as the ratio of the width of the displayed image to its height. The actual size of the image is specified as the viewable diagonal. Thus,  $AR=h/v$ , where  $h$  and  $v$  are the horizontal and vertical dimensions, respectively, of the displayed image, and DM,  $h$  and  $v$  forms a right triangle so that

$$DM^2 = v^2 + h^2$$

But since

$$AR = h/v$$

then

$$v = \frac{h}{AR}$$

Substituting Equation 3 into Equation 1,

$$DM^2 = \left( \frac{h}{AR} \right)^2 + h^2$$

Factoring,

$$DM^2 = h^2 \left( 1 + \frac{1}{AR^2} \right)$$

Taking the square root of both sides

$$DM = h \left( 1 + \frac{1}{AR^2} \right)^{1/2}$$

or

$$h = DM \left( 1 + \frac{1}{AR^2} \right)^{-1/2}$$

If the sweep is linear, the ratio of the width of the blip to the active scan time is the same as the ratio of the allowable convergence error to  $h$ . That is,

$$\frac{PW}{AST} = \frac{CE}{h}$$

Solving for the pulse width

$$PW = CE(AST)/h$$

Substituting Equation 7 into Equation 9 and simplifying

$$PW = \frac{CE(AST)}{DM} \left( 1 + \frac{1}{AR^2} \right)^{1/2}$$

Consider the following specific example where the values of the terms are  $DM=40$ ,  $AR=1.33$ , and

$AST=50 \mu\text{sec}$ . The allowable convergence error is  $\pm 1/32$ . Thus,

$$PW = \frac{(1/32)(50 \times 10^{-6})}{40} \left( 1 + \frac{1}{1.33^2} \right)^{1/2} = 48.82 \text{ ns}$$

Assuming a Gaussian rolloff, 10%-90%-10% drive leads to

$$BW = 2 \left( \frac{0.35}{PW} \right) = 14.32 \text{ MHz}$$

(Eq. 1) In contrast, consider the example of the system disclosed by Ghaem-Maghani and Holshouser in application Ser. No. 423,906 (now U.S. Pat. No. 4,485,394).

(Eq. 2) The 3.58 MHz fed to the horizontal counter in that system limits the horizontal resolution:

$$1/3.58 \text{ MHz} = 279.3 \text{ ns}$$

(Eq. 3) The active scan time is  $50 \mu\text{s}$ ; therefore, each horizontal scan can be divided into

$$\frac{50 \mu\text{s}}{279 \text{ ns}} = 179 \text{ counts.}$$

(Eq. 4) A 40" projection receiver has a horizontal screen dimension of  $0.8(40)=32$  inches. Thus, the finest resolution of which the Ghaem-Maghani and Holshouser system is capable is

$$(Eq. 5) \quad 32/179 = 0.179".$$

In contrast, the present invention is capable of converging to within  $1/32"$  (0.03125). This represents an improvement in the convergence error of almost six times. Obviously, the digital clocking scheme of Ghaem-Maghani and Holshouser can be improved by increasing the number of bits in the horizontal counter and clocking it at a faster rate. The present invention offers a simpler solution.

(Eq. 6) FIG. 7 shows the light sensor circuit used in the system of FIG. 5. A sensitive photodiode D2 is provided with an aperture (not shown) so that it will respond to the blip of light only if it occurs at the correct physical location. The diode D2 may be a Siemens BPW34 or equivalent and is connected in the base-collector circuit of an NPN transistor T9 having a gain of 200. The collector and emitter leads of transistor T9 are respectively connected by twisted pair to the +5 V supply and a load resistor R2. Thus, the transistor is connected as an emitter follower. The load resistor R2 is part of an RC bandpass filter F1 which is connected to the positive input of operational amplifier A3. Negative feedback for amplifier A3 is derived from an voltage divider to provide a gain of 100. The output of amplifier A3 is connected to a diode D3 followed by a low pass RC filter F2. The diode D3 and the filter F2 function as a peak detector to provide an output pulse to the microprocessor 34 (see FIG. 5) when a blip of light falls on the photodiode D2.

(Eq. 7) In FIG. 8, the switched current source circuit comprises a transistor T10 which acts as a gated current source. Transistor T11 is used to reset the sample and hold circuits before a charging current is supplied by

transistor T10. A 3-bit binary input to the switch 46 from the microprocessor 34 selects one of six output lines to which the junction of the collectors of transistors T10 and T11 is connected. The switch 46 may be implemented with a standard commercial CD4051 IC and functions as a one-of-six analog switch controlled by the three-bit binary code supplied by the microprocessor 34. The six output lines of switch 46 are connected to the inputs of the sample and hold circuits each of which comprises a capacitor and an operational amplifier. Thus, when the microprocessor selects one of the sample and hold circuits, the capacitor for that circuit is first discharged by a reset pulse to the base of transistor T11. Then, the current supplied by transistor

T10 charges the selected capacitor to a voltage determined by the duration of the pump pulse from the microprocessor 34 so that a correcting voltage is supplied at the output of the appropriate operational amplifier.

Returning now to FIG. 5, the microprocessor 34 is provided with a nonvolatile random access memory (NOVRAM) 36. The NOVRAM is preferably used to store factory setup data, e.g. nominal values for convergence are stored there during production. The microprocessor then uses this data as a starting point for convergence correction. The following listing is a specific example of a program which may be used in the practice of the invention. This listing is in assembly language for a Z80 microprocessor.

```

1          ;*****
2          ;SUBROUTINE /INIT/.SETS UP PORT A AS OUTPUT,PORT B AS
3          ;UNLATCHED INPUT, AND ZEROES SCRATCHPAD(12 BYTES START
4          ;AT 2100H) AND ACCUMULATOR
5          ;INPUTS-NONE
6          ;OUTPUTS-A,SCRATCHPAD
7          ;USES-A,B,F,H,L
8          ;DESTROYS-A,B,F,H,L
9          ;CALLS-NONE
10         ;*****
11         ORG 1200H
12 1200 3E0F INIT: LD A,0FH ;SET UP PORT A AS OUTPUT
13 1202 D382 OUT (82H),A
14 1204 3EFF LD A,0FFH ;SET UP PORT B AS INPUT
15 1206 D383 OUT (83H),A ;BIT CONTROL MODE-ALL BITS INPUT
16 1208 D383 OUT (83H),A
17 120A 3E07 LD A,07H ;DISABLE INTERRUPTS FROM PORT B
18 120C D383 OUT (83H),A
19 120E 3E00 LD A,00H
20 1210 210021 LD HL,2100H ;POINT TO BEGINNING OF SCRATCHPAD
21 1213 060C LD B,0CH ;SET COUNT =12
22 1215 77 LP: LD (HL),A ;STORE ZERO
23 1216 23 INC HL ;POINT NEXT
24 1217 10FC DJNZ LP ;REPEAT UNTIL DONE
25 1219 C9 RET
26
27
28
29
30
31
32         ;*****
33         ;SUBROUTINE /ANOUT/. SELECTS OUTPUT LINE AND SENDS 'B'
34         ;OUTPUT PULSES TO IT.
35         ;INPUTS-C:OUTPUT LINE
36         ; B:NUMBER OF PULSES TO SEND
37         ;OUTPUT-PORT 80H
38         ;USES-A,B,C,F,H,L,2 STACK LEVELS:
39         ;DESTROYS-NONE
40         ;CALLS-NONE
41         ;*****
42 1220 F5 ANOUT: ORG 1220H
43 1221 C5 PUSH AF
44 1222 79 PUSH BC
45 1223 E607 LD A,C
46 1225 F630 AND 07H ;ISOLATE 3 LSB'S
47 1227 D380 OR 30H ;TURN ON BITS 4,5
48 1229 E3 OUT (80H),A
49 122A E3 EX (SP),HL ;WASTE 52 US TO WIDEN RESET PULSE
50 122B E3 EX (SP),HL
51 122C E3 EX (SP),HL
52 122D E6CF ANI: AND 0CFH ;SEND 'B' OUTPUT PULSES
53 122F D380 OUT (80H),A ;TURN OFF BITS 4,5
54 1231 F610 OR 10H ;TURN ON BIT 4

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55 1233 D380      OUT (80H),A
56 1235 10F6      DJNZ AN1      ;REPEAT UNTIL B=0
57 1237 C1        POP BC
58 1238 F1        POP AF
59 1239 C9        RET
60
61
62
63
64
65 ;*****
66 ;SUBROUTINE /VSYNC/. WAITS UNTIL THE LEADING EDGE OF
67 ;VERTICAL SYNC PULSE, THEN RETURNS
68 ;INPUTS-BIT 7,PORT 81H
69 ;OUTPUTS-NONE
70 ;USES-A,F,1 STACK LEVEL
71 ;DESTROYS-NONE
72 ;CALLS-NONE
73 ;*****
74      ORG 1240H
75 1240 F5      VSYNC: PUSH AF
76 1241 DB81      VS1: IN A,(81H) ;WAIT UNTIL BIT 7 IS HIGH
77 1243 E680      AND 80H
78 1245 28FA      JR Z,VS1
79 1247 DB81      VS2: IN A,(81H) ;WAIT UNTIL BIT 7 IS LOW
80 1249 E680      AND 80H
81 124B 20FA      JR NZ,VS2
82 124D F1        POP AF
83 124E C9        RET
84
85
86
87
88
89
90 ;*****
91 ;SUBROUTINE /INCHK/. CHECKS BITS 0 AND 1 (LIGHT SENSOR
92 ;IF ONE OF THESE BITS GOES LOW, THE CORRESPONDING BIT
93 ;IN THE E REGISTER IS SET LOW. IF NEITHER BIT GOES LOW
94 ;THIS ROUTINE TIMES OUT IN 10.5 MS AND RETURNS WITH
95 ;ZERO IN THE E REGISTER
96 ;INPUTS-BITS 0,1 OF PORT 81H
97 ;OUTPUTS-E=03;NEITHER BLIP WAS FOUND
98 ;E=02;BLIP ON MAJOR AXIS WAS FOUND
99 ;E=01;BLIP ON MINOR AXIS FOUND
100 ;E=00;BOTH BLIPS FOUND.
101 ;USES-A,B,C,E,1 STACK LEVEL
102 ;DESTROYS-A,E,F
103 ;CALLS-NONE
104 ;*****
105      ORG 1250H
106 1250 C5      INCHK: PUSH BC
107 1251 010300   LD BC,0003H
108 1254 DB81      INCK: IN A,(81H)
109 1256 A1        AND C
110 1257 4F        LD C,A
111 1258 E3        EX (SP),HL ;WASTE 25 US
112 1259 E3        EX (SP),HL
113 125A 00        NOP
114 125B 00        NOP
115 125C 00        NOP
116 125D 10F5     DJNZ INCK
117 125F 59        LD E,C
118 1260 C1        POP BC
119 1261 C9        RET
120
121
122
123
124
125 ;*****
126 ;SUBROUTINE /CHVAL/. GENERATES OUTPUT VALUES IN THE B
;REGISTER IN THE SEQUENCE 18H,17H,19H,16H,1AH,...,01H,

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127 ;IF THIS RANGE IS EXCEEDED, TRAPS TO ERROR ROUTINE
128 ;LOCATED AT 2050H. STORES OFFSET FROM 18H IN SCRATCHPAD
129 ;RAM FOR EACH OUTPUT LINE
130 ;INPUTS-C:3 LSB'S SPECIFY WHICH RAM LOC. IS TO BE CHAN
131 ;OUTPUTS-B
132 ;USES-A,B,C,H,L,2 STACK LEVELS, SCRATCHPAD RAM
133 ;DESTROYS-B
134 ;CALLS-NONE
135 ;*****
136 ORG 1270H
137 CHVAL: PUSH AF
138        PUSH HL
139        LD A,C
140        AND 07H ;ISOLATE 3 LSB'S
141        LD H,21H ;BUILD POINTER TO SCRATCHPAD RAM
142        LD L,A
143        PUSH HL ;SAVE POINTER
144        ADD A,06H ;ERROR MEMORY OFFSET
145        LD L,A
146        LD A,(HL) ;GET ERROR
147        POP HL ;RETRIEVE POINTER
148        OR A ;TEST IT
149        JR Z,NEXT ;IF NO ERROR, RESUME PROCESSING
150        LD A,00H ;ELSE, SET DISP=0
151        JP STOR
152        LD A,(HL) ;GET OLD DISPLACEMENT FROM RAM
153        BIT 7,A ;CHECK THE SIGN
154        JR NZ,NEG ;DON'T INCREMENT IF NEGATIVE
155        INC A
156        CP 18H ;OUT OF RANGE?
157        CALL NC,2050H ;IF SO, CALL ERROR ROUTINE
158        CPL A ;NEGATE (COMPLEMENT&INCREMENT)
159        INC A
160        STOR: LD (HL),A ;STORE NEW DISPLACEMENT IN RAM
161        ADD A,18H ;ADD OFFSET
162        LD B,A ;SEND TO B
163        POP HL
164        POP AF
165        RET
166 ;
167 ;
168 ;
169 ;
170 ;
171 ;*****
172 ;ROUTINE /ERROR/. SETS ERROR FLAG IN RAM BYTE
173 ;INPUTS-HL POINTS TO 6 BELOW ERROR BYTE
174 ;OUTPUTS-01H AT (HL+6)
175 ;USES-A,H,L
176 ;DESTROYS-A (RESTORED BY /CHVAL/)
177 ;CALLS-NONE
178 ;*****
179 ORG 2050H
180 ERROR: PUSH HL
181        LD A,L ;BUILD PTR TO ERROR BYTE
182        ADD A,06H
183        LD L,A
184        LD A,01H
185        LD (HL),A ;STORE ERROR FLAG
186        POP HL ;RETRIEVE POINTER
187        RET ;RETURN TO /CHVAL/
188 ;
189 ;
190 ;
191 ;
192 ;
193 ;*****
194 ;MAIN PROGRAM /ACV/.

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195 ; INPUTS-
196 ; OUTPUTS
197 ; USES-A,B,C,D,F,H,L,SCRATCHPAD,STACK
198 ; DESTROYS-ALL
199 ; CALLS-INIT,ANOUT,CHVAL,INCHK,VSYN
200 ; *****
201 ORG 2000H
202 2000 CD0012 ACV: CALL INIT
203 2003 0E08 BEGIN: LD C,04H
204 2005 CD4012 CONT: CALL VSYNC ;WAIT HERE UNTIL RETRACE
205 2008 CB43 BIT 0,E ;TEST FOR MAJOR AXIS BLIP
206 200A C47012 CALL NZ,CHVAL ;IF NOT THERE, CHANGE DISP
207 200D CD2012 CALL ANOUT ;SET UP 4-POLE CURRENT
208 2010 0D DEC C
209 2011 CD4012 CALL VSYNC ;WAIT HERE UNTIL RETRACE
210 2014 CB4B BIT 1,E ;TEST FOR MINOR AXIS BLIP
211 2016 C47012 CALL NZ,CHVAL ;IF NOT THERE, CHANGE DISPLACEM
212 2019 CD2012 CALL ANOUT ;SET UP 4-POLE CURRENT
213 201C CD5012 CALL INCHK ;LOOK FOR BLIPS
214 201F 79 LD A,C
215 2020 B7 OR A
216 2021 28E0 JR Z,BEGIN ;IF LAST COLOR,START OVER
217 2023 0D DEC C

219 2025 18DE JR CONT ;CONTINUE
220 ;
221 ;
222 ;
223 ;
224 2027 END ACV

```

## SYMBOL TABLE

ACV	2000	AN1	122D	ANOUT	1220	BEGIN	2003
CHVAL	1270	CONT	2005	ERROR	2050	INCHK	1250
INCK	1254	INIT	1200	LP	1215	MEMORY	M 0000
NARG	0000	NEG	1291	NEXT	1286	STACK	S 0000
STOR	1293	VS1	1241	VS2	1247	VSYN	1240

I claim:

1. A system for the automatic correction of centering errors in a cathode ray tube display, said display having 45 a major axis and a minor axis perpendicular to one another, said system comprising:

a first masked light sensor positioned on said major axis and a second masked light sensor positioned on said minor axis, said first and second light sensors 50 being located outside the field of view of said display but within the scanned area;

light blip generator means responsive to horizontal and vertical timing pulses supplied to said cathode ray tube display for unblanking the video circuits 55 during the horizontal and vertical blanking intervals to thereby generate light pulses in the vicinities of said first and second light sensors; and

microprocessor feedback controller means responsive to the outputs of said first and second light sensors and connected to centering circuits in said cathode ray tube display for iteratively generating correction signals to the centering circuits whenever no output is received from one or the other or both of said first and second light sensors. 65

2. The system according to claim 1 wherein said cathode ray tube display is a color display, said system further comprising switch means connected to the out-

put of said light blip generator means and controlled by said controller means for sequentially providing unblanking signals to the red, green and blue video circuits, said controller means separately generating correction signals to the red, green and blue centering circuits.

3. The system according to claim 2 further comprising:

a plurality of first light sensors arranged perpendicular to said major axis on one side of said cathode ray tube display, one of said first plurality of light sensors being positioned on said major axis;

a plurality of second light sensors arranged perpendicular to said minor axis at the top of said cathode ray tube display, one of said second light sensors being positioned on said minor axis;

a plurality of third light sensors arranged perpendicular to said major axis on the opposite side of said cathode ray tube display from said first plurality of light sensors; and

a plurality of fourth light sensors arranged perpendicular to said minor axis at the bottom of said cathode ray tube display;

said controller means being responsive to each of said plurality of light sensors for generating signals to

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correct the dynamic convergence of said cathode ray tube display.

4. The system according to claim 2 wherein said controller means comprises:  
microprocessor means connected to receive outputs 5  
from said first and second light sensors and programmed to perform the iterative generation of said correction signals;

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sample and hold means for storing correction signals for each of the red, green and blue horizontal and vertical correction circuits; and  
switched current source means controlled by said microprocessor means for selectively charging said sample and hold means.

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